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By

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Research Report

ROTARY AUTOKINESIS AND DISPLACEMENT OF THE VISUAL HORIZONTAL ASSOCIATED WITH HEAD (BODY) POSITION*

Earl F. Miller, II and Ashton Graybiel 5 Mar. 1963

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SUMMARY PAGE

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THE PROBLEM

To determine the effect of body position (upright and recumbent), visual reference cues, and time upon egocentric visual localization.

FINDINGS

The visual horizontal as judged by four normal subjects (authors and two experienced test pilots) was recorded every two seconds during periods lasting up to twenty-three minutes. Each subject was tested in an upright, then in a recumbent (left side) position. In both positions the procedure was identical: Empirical visual cues serving as a background to the luminous line target were alternately illuminated for two minutes, then darkened completely for five minutes during each period.

It was found that a lack of visual cues did not appreciably influence the accurate and relatively stable localization of the horizontal in the upright position; however, in the recumbent position removal of these cues caused, after a brief lag period, a gradual spontaneous rotation of the phenomenal horizontal up to a maximum displacement typical for each subject. Superimposed upon these perceptual changes was the considerable fluctuant movement in horizontality which was described as a form of autokinesis (rotary). These illusions disappeared almost instantaneously when a visual framework was provided. Qualitatively, the time course of these perceptions was similar and highly reliable for all subjects. The pilot subjects, however, differed from the nonpilots by indicating a slightly greater time lag at onset, a slower rate in reaching the maximum deviation position, significantly less total deviation (about one-third), and less rotary autokinesis.

In a subsequent (recumbent) trial, two subjects, the authors, observed the target for thirty minutes in the dark. The error perceived remained essentially at the same level for one subject, but decreased significantly for the other.

AUTHOR

INTRODUCTION

Physical space coordinates parallel and perpendicular to gravity can be quite accurately located visually so long as man is kept upright with his head-body aligned (6,7,12,13,17). Normally under these postural conditions the lack of surrounding visual cues does not significantly influence the precision of these judgments; however, when man lies on his side, oriented parallel to the physical horizontal, a luminous line in the dark will normally appear obliquely inclined. This subjective phenomenon (A-phenomenon) was first described by Aubert (1) who noted, when he was inclined from the upright, that his target always appeared inclined in a direction opposite his head tilt. Considerable information about this illusion has appeared in the literature since Aubert's original work. These reports, however, are mostly in the form of qualitative observations or restricted to moderate degrees of tilt from the vertical and do not permit a satisfactory analysis of the mechanism(s) subserving the illusion. It is generally held that the perception of horizontal (or vertical) is a function of visual and postural cues, but few studies have been made to determine their mode of action or interaction. The present experiment represents an attempt to extend our knowledge of visuo-postural interactions by obtaining quantitative data on visual orientation using posture, visual reference cues, and time as parameters.

PROCEDURE

SUBJECTS

Four healthy military officers were tested; two were the authors (nonpilots) and the other two were highly experienced test pilots who had had special training in tilt devices. All had some experience in making critical visual judgments but only one author (GR) had been a subject for any study involving methods closely related to those now described.

APPARATUS

The experiment was conducted in a completely dark room containing an inner cubicle within which the subject either sat or lay on his side (Figure 1). When the subject was seated on the stool, his head was stabilized by a chin and forehead rest; when on his left side, his head and shoulders were secured by means of a molded fiberglas appliance and his body rested on a 4-inch foam rubber mattress. A narrow line of collimated light, broken at the center to form a star, was used as the target. This target could be rotated about its center in a clockwise or counterclockwise direction and at variable speeds by means of a hydraulic power system which could be activated by the subject or experimenter. The rotary position of the target to the nearest 0.25 degree relative to true horizontal was indicated on a dial 18 inches in diameter, located outside the cubicle. A lamp containing a 75-watt bulb was used to light the interior of the cubicle which contained several strong vertical and horizontal contour cues. When these lights were turned off, the surroundings were completely dark save for the luminous target. An electronic timer was used to signal every two seconds.

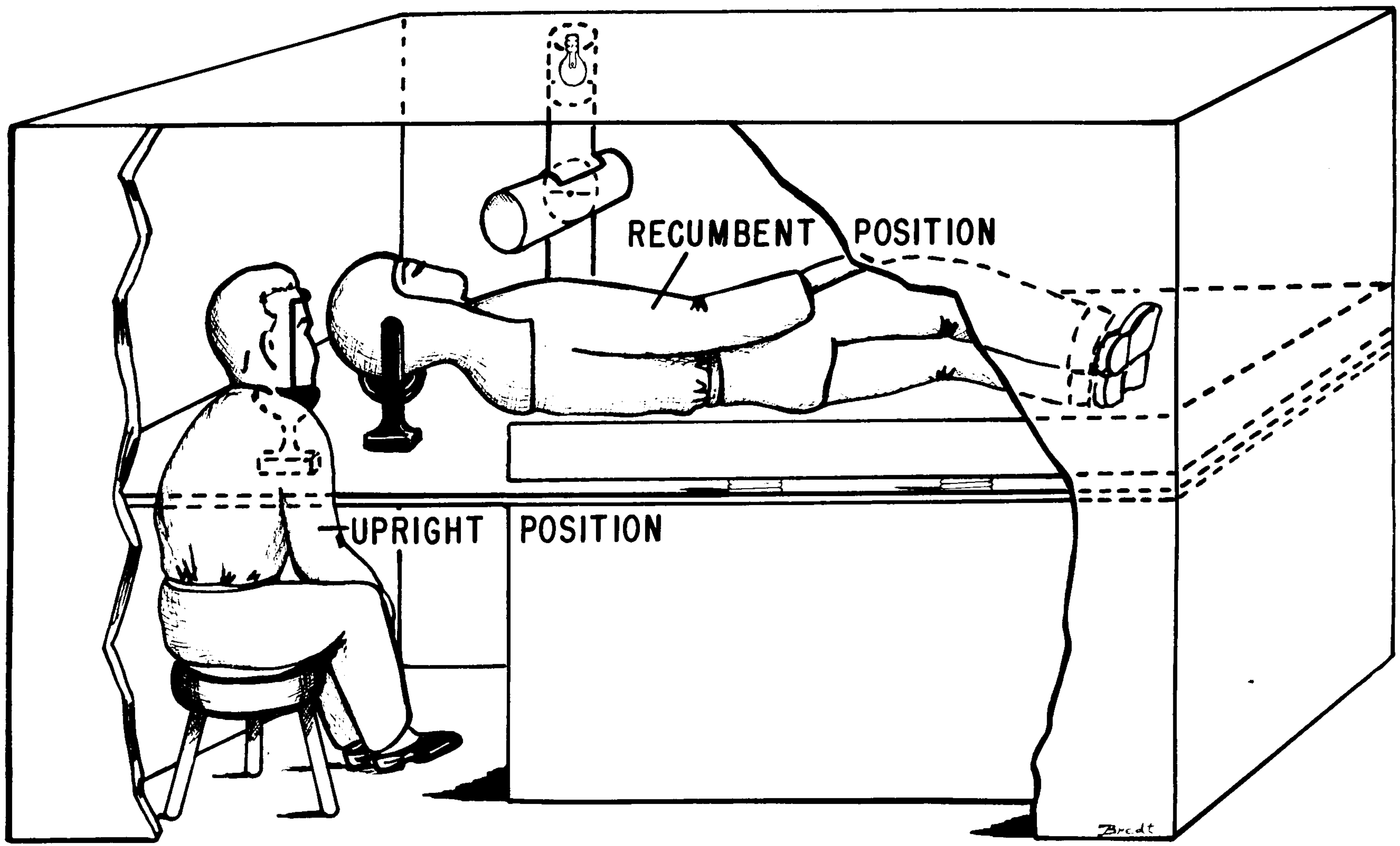

Figure 1

Diagram of Apparatus Used to Determine the Location of Visual Horizontal with the Subject in Upright or Recumbent Position

METHOD

The subject assumed the seated or recumbent position shown in Figure 1. The target was precisely adjusted so that it appeared directly before the subject's right eye at a distance of about 1.5 meters; the left eye was occluded with an opaque patch. A round knob controlling the hydraulic power system and rotation of the target was placed in his right hand. This system had the important advantage of providing no tactual cues of position of the line or of the horizontal. Initially, each subject was assigned a short period in which to acquaint himself with the mechanics of the control and target movement.

The subject's task was simply to adjust the luminous line so that it always appeared horizontal. For this judgment he was carefully instructed to regard the target as a remote object without consciously referring its position to that of his body. The right and left members of the target were to be imagined as the wings of a distant aircraft which rendered the setting of the target to horizontal equivalent to "leveling" the aircraft.

Each subject was tested first in the seated, upright position. With the background light on and the subject visually oriented to his surroundings, the experimenter offset the unilluminated target. On signal, the target was illuminated and the subject, as instructed, rotated it as quickly as possible to its position of the subjective horizontal. Thereafter, continuous corrective adjustments of the target for even the slightest apparent inclinations were made to maintain its horizontality. The position of the target as indicated on the instrument dial was recorded every two seconds throughout the twenty-three minute test period. The background was illuminated initially for two minutes, then darkened completely for five minutes. This light-dark cycle was repeated two additional times, and the test sessions were terminated with an additional two-minute light period. After a short rest period this procedure was repeated with the subject in the recumbent position. On a subsequent day the nonpilot subjects were given an additional test in the recumbent position but with this test the background remained dark for the entire test period of thirty minutes.

RESULTS

The data involving visual perception of the horizontal in an upright and recumbent (left side) position are presented in Figure 2 for the four subjects. Data collected during periods in which the visual field was illuminated or dark are plotted against a white or a stippled grey background, respectively. The X-axis denotes duration in minutes. The data with respect to this time axis were corrected for the lag between the perceived change and the registration of the corrective response. This lag factor, measured to be approximately two seconds, was subtracted from the time required to make any change in setting. Since the position of the star as indicated on the dial was recorded on signal from the electronic timer every two seconds, any perceived positional change of the star between recordings would be represented as instantaneous (Figure 2). The Y-axis represents the apparent inclination of the luminous line; positive values indicate inclinations in the same direction as lateral head(body) tilt; minus values those in the Aubert direction.

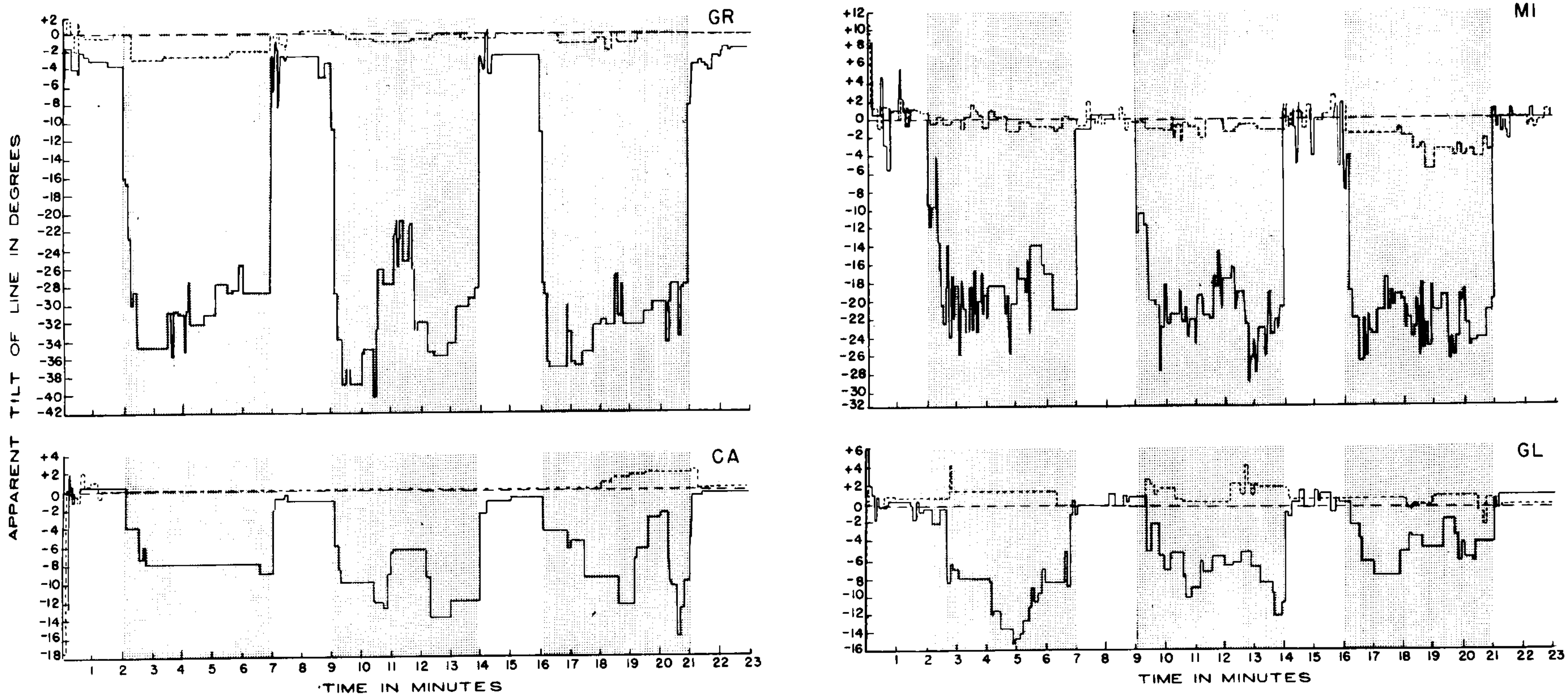

Figure 2

Time Course of Perception of Horizontality for Each Subject in Upright (Broken Line) or Recumbent (Continuous Line) Posture with (Unshaded Strips) and without (Shaded Strips) Visual Reference Cues

From the data plotted as a dotted line in Figure 2 it can be seen that, in the upright posture, all subjects performed almost equally well. The apparent tilt of the target varied only slightly from zero, for the most part within $\pm$ 2 degrees of its true position. When slightly greater apparent deviations occurred, they tended to do so more during the periods in which empirical visual background cues were absent. The differences in error under light or dark background conditions, however, were not consistent and in most cases small in amount so that little importance can be attached to empirical visual cues with the subject upright as was found in other studies (6,7,12,13,17). These same cues, however, played a highly significant role in the judgment of visual horizontal when the individual was placed on his side.

In the recumbent posture, all subjects manifested significant errors always in the Aubert direction when background cues for visual orientation were absent. It can be seen that, after the background was darkened, the target appeared, after a certain time lag, to rotate away from physical horizontal and characteristically required several seconds to reach its average maximum error position. On the other hand, introduction of visual cues (dark-light phase junctures, Figure 2) brought about an immediate recognition of the gross error in position of the target and its rapid correction to one approximating physical horizontal; the largest deviation (Subject GR) amounted to less than 3 degrees. The target remained approximately in this position throughout each of the periods in which the background was illuminated. The high reliability of these data is indicated by the great similarity in the response of a given subject during successive dark and light periods.

Superimposed upon these constant error changes were those of variable error (Figure 2). Marked fluctuations of the phenomenonal horizontal occurred for all subjects when they were recumbent and without a visual framework for reference. These oscillatory changes in localization of the horizontal for the most part were continuous and resembled autokinetic movement.

Although qualitatively similar responses were found among the subjects for all parameters, the data revealed significant quantitative differences. On the basis of magnitude of error (dark phase, recumbent posture) the subjects could be divided into two pairs, non-pilots (GR and MI) and pilots (GL,CA). Subject GR exhibited usually more than 30 degrees of error, while the estimations of subject MI differed from true horizontal by usually more than 20 degrees. Both pilot subjects were apparently less handicapped by the lack of visual cues in the recumbent position since they manifested errors amounting to approximately one-third those of the authors. Additional evidence of their relatively less dependence upon visual cues for visual localization is revealed in their greater stability (fewer and smaller rotary oscillations) in the perception of the horizontal. The slightly greater lag in the perception of the onset and the slower rate in reaching the maximum level of the illusion further denote a greater "resistance" of the pilot subjects to the illusion.

In order to determine the time course of the illusion for periods longer than five minutes without visual background cues, the authors in the recumbent position continuously adjusted the target so that it appeared horizontal during the entire thirty-minute test period. The record of each subject is presented in Figure 3. In the case of MI a gradual and significant decrease in the average error (apparent tilt) from the initial to final three minutes was found, whereas no significant changes in error were manifested by subject GR. Figure 3 further reveals that the rotary oscillations tended to increase slightly in amplitude and frequency with time of observation for both of these subjects.

DISCUSSION

The continuous recording of egocentric visual localization provided a quantitative measure of the interaction between visual and nonvisual cues as a function of time and posture. It was to be expected that, with visual cues present, aligning the target to the horizontal would be accomplished easily and accurately. The overwhelming influence of these cues persisted even for a brief period after their removal, then rather slowly decayed, so that, finally, judgments probably were completely dependent upon nonvisual cues. The relatively slow process of shifting from a visual to a postural frame of reference was indicated also in Clark and Graybiel's report (3) of a gradual increase in the oculogravic illusion as a function of time following removal of visual cues. Vestibular, kinesthetic, and other nonvisual cues apparently acted or interacted in the present study to provide adequate information for precise visual egocentric localization when the subject was upright, but when recumbent these cues were much less effective; judgments became grossly inaccurate and unstable. The individual mechanisms responsible for these illusions have not been identified but are generally grouped together as proprioceptive. Recent evidence, however, has been found to indicate that at least one component of the system (vestibular apparatus) acts to reduce the magnitude of the illusion (9) and of autokinetic movement (8).

The degree of dependence upon visual cues for correct visual orientation is indicated by the magnitude of the constant and variable error when vision is restricted to the linear target. It was seen that the pilot subjects manifested significantly less error and somewhat greater stability than the author subjects under this condition. The most apparent experiential difference between these pairs of subjects is that of the considerable training in orientation by the pilots in flying, plus special training in various rotating and tilting devices. Any difference that might have resulted from experience in psychophysical visual judgments should have favored the authors. Since the sample is so small and the large interindividual differences in the extent of the illusion may be due to other causes (10, 16), one can only conjecture that visuo-postural interaction subserving this perception might have been improved in some way through training. Evidence that judgments based upon nonvisual cues are amenable to practice is furnished by several studies (4, 14, 15) involving the postural vertical. Bitterman and Worchel (2) found that with body tilted, congenitally blind subjects were better oriented to the principal axes of space than were normal subjects deprived of vision, indicating that practice without adequate visual cues

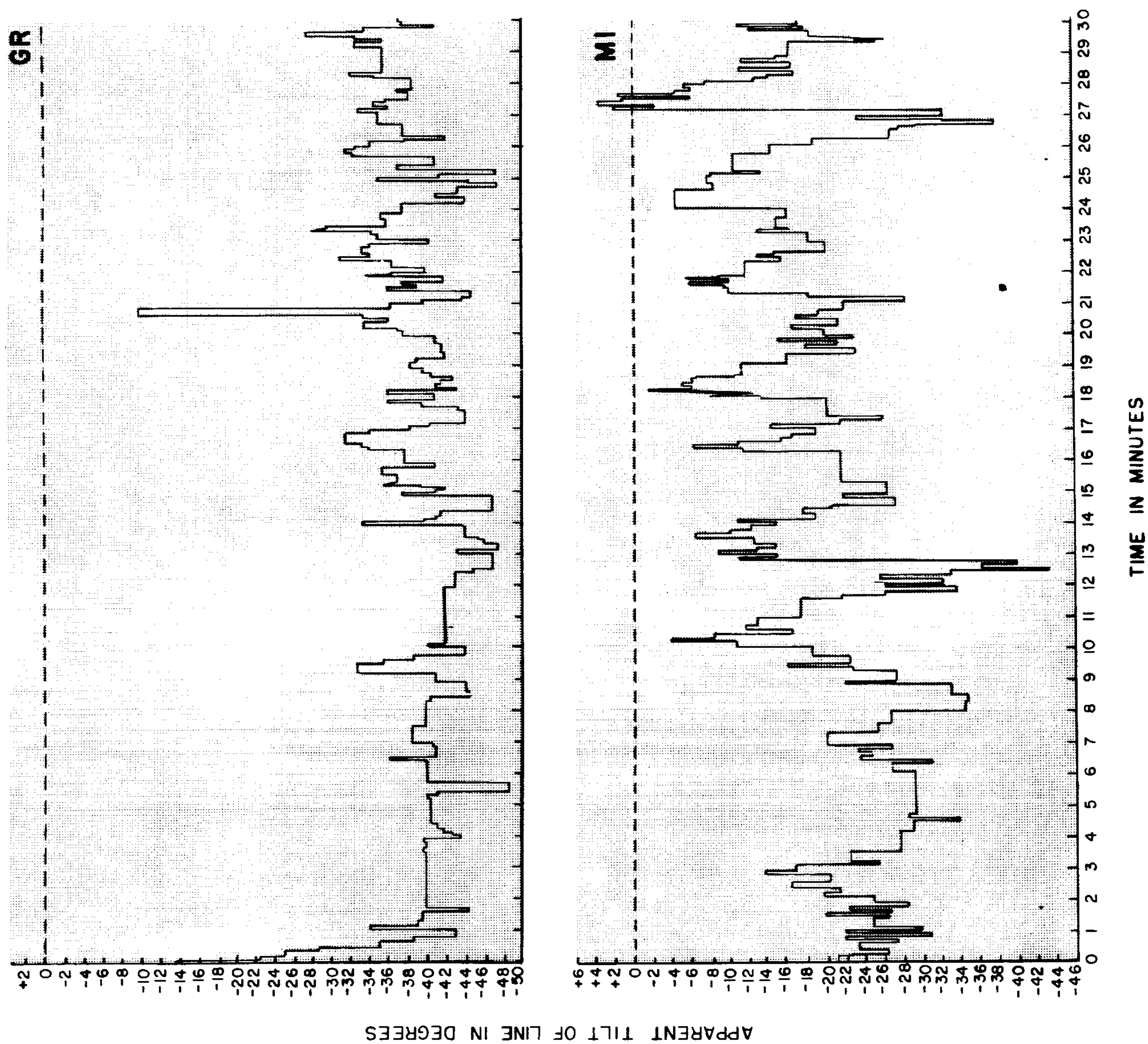

Figure 3

Time Course of Visual Localization of Horizontal by Each Author Subject in Recumbent Position and with Visual Background Completely Dark which normally dominate may improve orientation by postural cues alone. Clark and Graybiel (4), furthermore, demonstrated that improvement in postural judgments is possible even when normal vestibular cues are absent as in their group of labyrinthine-defective subjects.

A decrement in the visual illusion was found in the present study for one of the author subjects (MI) during prolonged observation. Without visual cues and without knowledge of the physical position of the target this perceptual change cannot be attributed to learning in the usual sense. Moreover, several previous observations revealed that, during prolonged observation, illusory changes are highly variable among subjects and may be in the direction of increased error. Nagel (12) observed that the phenomenal tilt of his target seemed to increase with time of observation and inclination; whereas, Cyon (5) reported that the A-phenomenon appeared more marked with a brief than with a sustained presentation of the target. Müller (11) in his extensive observations of the phenomenon was able to type his subjects on the basis of their perceived increase, decrease, or constancy in rotary position error as a function of observation time. Obviously, further quantitative studies of the effect of training upon this dimension of visual space perception are needed.

The changes in localization of the visual horizontal as described here were not found to be discrete in most cases but appeared continuous in time. These perceived movements deserve special mention since they have never previously been described in a systematic, quantitative fashion and are not usually recognized as part of the general classification of apparent, seen motion. This is surprising since the oscillatory movement of one's visual horizontal with head tilted and vision restricted to a linear reference mark is readily perceived and has been known since Aubert's original publication on this phenomenon(1). The present study provides quantitative information concerning the character of these illusory movements. It should be pointed out that, although every effort was expended in this study to have corrections made for even the slightest displacement of the target, the spontaneous fluctuations were at times so slight and fleeting that no adjustment was possible. Furthermore, the movement was not always restricted to the fronto-parallel plane and at times differential movement of parts of the star was noted. These illusory rotary movements occurring during prolonged observation resemble those classically described as autokinetic. Nagel (12) was first to note the similarity between illusory movement of a point of light and rotary fluctuations of a linear light source. Since autokinesis as it is usually defined is apparent movement of an object in any or all directions, it seems reasonable to identify the illusory oscillations of a linear target about the line of sight as rotary autokinesis. Since the genesis of autokinesis has not been fully analyzed, rotary autokinesis cannot be differentiated on this basis from the translational movement type and indeed may have the same underlying mechanism(s). Both types of movements were observed, in some instances simultaneously, in the present study and in that of Nagel (12).

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